# ESTUARINE AND MARINE HABITAT

Massachusetts is located at the intersection of two biogeographic regions, the Virginian and Acadian provinces. Biogeographic regions are identified by distinct differences in biological communities, physical characteristics, and weather patterns. Cape Cod forms the boundary between the two provinces. The Acadian province is north of Cape Cod and encompasses the Gulf of Maine ecosystem. Waters south of Cape Cod are in the Virginian province, including Buzzards Bay, and are representative of northern Mid-Atlantic Bight waters. These two regions support a diversity of physical features and biological communities. Although differences exist, there are also overlapping characteristics between the Virginian and Acadian provinces in Massachusetts. The biogeography north and south of Cape Cod make Massachusetts a region of relatively high biological and habitat diversity. The diversity in environmental resources of Massachusetts is obvious by the marked variability observable along the Massachusetts coast, such as the distinct variation in the rocky shoreline of Cape Ann and sandy beaches of Cape Cod.

Habitat is a term that evokes debate and is often difficult to describe because there are different perspectives on its definition. Habitat is generally thought of as a place where an organism is found, such as estuaries, salt marsh, seagrass, and cobble fields (Odum 1971). Describing habitat is complicated by issues of scale and complexities in natural resources. Right whale habitat is described in terms of oceans (1000s km), while juvenile fish habitat is described by unique seafloor characteristics or microhabitats (cm to m). In spite of how habitat is described and issues of scale, the ocean environment in Massachusetts contains a diversity of environmental resources that support a diversity of organisms and life history stages.

Human-induced perturbations and natural processes influence the abundance, quality and functions of habitats and environmental conditions in Massachusetts. Large storms and ice scour, for example, can substantially change the quality of nearshore seafloor habitats. However, these naturally occurring processes do not affect estuarine and marine habitat to the extent of human activities. Human activities have dramatically altered the extent and quality of estuarine and marine habitats throughout the state. Pollution, eutrophication, coastal alteration and fishing practices have wide ranging impacts to habitat. Depending on habitat type, geographic location, and type and extent of human impact, the ecological consequences of anthropogenic degradation can greatly vary. While the variety of human-induced impacts are not thoroughly documented through time, the effects of many types of impacts are understood and warrant mention in this report.

This section of the Technical Report summarizes data for select estuarine and marine habitats. Habitat features are described for nearshore and offshore systems. Given the inherent relationship between living marine resources (Technical Report #5) and habitats (Technical Report #6), there is overlap in the description of particular resources (e.g., American lobster and habitat associations). This report does not attempt to describe habitat for specific animals, but provides an overview of recognized systems (i.e., salt marsh, tidal flats and seagrass), environmental features that influence habitats, such as seafloor geology, water depth and topography, relatively unevaluated habitat types, and a general summary of human-induced threats and natural processes that affect habitat.

Where available, data on specific habitat conditions and species (e.g., salt marsh and eelgrass habitats) are described in detail; however, the distribution and abundance of many habitats and environmental features are unknown in Massachusetts. The functions of particular habitat characteristics, such as the sedimentary environment of the ocean floor, are summarized, but this section is not a comprehensive review of all species, communities, or ecological services associated with the habitat.

Odum, E.P. 1971. Fundamentals of Ecology. W.B. Saunders Co. Philadelphia, PA. 544pp.

## 1. ESTUARINE AND MARINE WETLAND HABITAT

Before describing wetland habitats, a word about what we mean when we use the term, "Wetland." It is a term that includes a wide variety of marshes, swamps and bogs, and coastal resources and landforms (e.g., beach, rocky intertidal and submerged habitats). Wetland habitats are found throughout terrestrial and coastal areas in Massachusetts. The Massachusetts Wetlands Protection Act identifies "Land Under the Ocean," "Coastal Beaches and Dunes," "Barrier Beaches," "Coastal Dunes," "Rocky Intertidal Shores," "Salt Marshes," "Land Under Salt Ponds," "Land Containing Shellfish," and Fish Runs" as coastal wetland resources and regulates activities in these habitats. Wetland resources are also classified in terms of their ecological characteristics. The ecological classification of wetlands is based on hydrology, vegetation, and substrate and are grouped into five distinct systems (palustrine, lacustrine, riverine, estuarine, and marine; see Cowardin et al. 1979). Wetland habitats, regardless of the classification and regulation, are important coastal resources and provide a number of ecologic and economic roles and services.

This section describes tidal wetlands, including estuarine and marine salt marsh and tidal flat habitat. The omission of other coastal wetland resources (e.g., coastal banks, salt ponds, beaches and dunes) that are critically important in Massachusetts does not discount their importance.

Vegetation and animal communities of salt marsh and tidal flat systems are variable in Massachusetts on regional and local scales (see Nixon 1982 and Teal 1986). Vegetation communities in salt marshes are more stable and predictable compared to animal communities. *Spartina alterniflora* and *S. patens* generally dominate vegetation communities, with several other plant species (e.g., *Salicornia sp., Distichlis spicata, and Juncus gerardii*) contributing to overall salt marsh vegetation community diversity. Tidal flats appear at lower tides as unvegetated areas of mud and sand. The mud and sand contain abundant microscopic plants, such as diatoms, algae and dinoflagellates, and a diverse invertebrate community. The invertebrate community can contain valuable commercial and recreational shellfish (e.g., soft-shell clams). Regions with large tidal regimes have more area of tidal flat habitat. For example, there are larger areas of tidal flat in Massachusetts Bay compared to southern New England.

Ecological and economic functions of marine and estuarine wetlands are diverse and include fish, invertebrate, insect and wildlife habitat; primary production and organic matter exportation; water quality maintenance; flood protection; and shoreline erosion protection. The aesthetics of open space, nature recreational activities (e.g., shellfishing, wildlife observation and photography), commercial shellfishing, education opportunities, and agriculture (e.g., haying) are highly valuable socio-economic attributes of coastal wetlands (Tiner 1984).

The perception of wetland value has dramatically changed through time. Wetlands were once considered wastelands, but scientific studies demonstrated the importance of wetland resources and increased public awareness of wetland functions (Tiner 1984).

The increase in public awareness led to laws specifically designed for wetlands protection, and Massachusetts passed the Wetlands Protection Act in 1963. The federal government followed by adding wetland protection provisions to the Clean Water Act (1970s) and Section 10 of the River and Harbor Act of 1899. These laws and the increased understanding and appreciation of resource values slowed the destruction of wetlands.

Wetland resources, including salt marsh and tidal flat habitat, are mapped by the Massachusetts DEP Wetland Conservancy Program with support from the University of Massachusetts at Amherst (MassGIS 2003). Coastal habitats were mapped in the 1990s and the focus is on completing the entire state before updating existing maps. The National Wetland Inventory (NWI) of the US Fish and Wildlife Service (USFWS) also maps wetlands and has completed the entire state, though the date, scale, and accuracy of the NWI maps vary. Despite this strong body of information on the location and type of wetland resources (i.e., wetland quantity), there is limited information documenting historical wetland losses and only scarce data are available regarding the status of wetland condition or quality (B. Carlisle personal communication). This section summarizes major influences to wetland distribution and quality, describe national trends (noting Massachusetts-specific information, where available and appropriate), and describe the current distribution of salt marsh and tidal flat habitat in Massachusetts.

## ANTHROPOGENIC AND NATURAL INFLUENCES OF ESTUARINE AND MARINE WETLANDS

Prior to the passage of the Massachusetts Wetlands Protection Act (1963), countless acres of salt marsh and tidal flat habitat were filled, drained and dredged to support the development and growth of urban and residential areas and agricultural lands. Substantial wetland filling occurred for over three centuries in Massachusetts (1600s-1900s). New direct filling and draining are currently not large problems, although loss of wetlands remains a problem. Indirect alteration to wetland quality through changes in tidal hydrology, watershed development, and pollution continues to degrade large areas of coastal wetlands. Natural processes, such as sea level rise, subsidence and severe weather (droughts and ice scour) also influence wetland distribution and quality.

The rate of sea level rise, tidal regime, sediment supply, and the ability of plants to adapt to salinity change affect the persistence of existing wetlands and development of new wetlands. Sea level rise and subsidence are natural processes. Vertical accretion of sediments and horizontal migration of the wetland must offset sea level rise and wetland submergence (subsidence) to maintain wetland resources. If sea level rise and/or submergence rates are greater than accretion and/or migration rates, wetland resources will change into open water habitat (see Teal 1986 for summary). Tidal wetlands, since the glacial period, migrated inland along estuaries, river valleys and coastal slopes or were replaced by open water (Harris MS). The natural migration and evolution of wetland resources is complicated by human development of coastal lands. Estuarine and marine wetlands that are surrounded by development do not have the ability to migrate upland, thereby prohibiting the natural evolution of landscapes. Furthermore, sediment supply, sedimentation rates, and water flow are frequently altered in these areas compounding effects to wetland succession.

Watershed and coastal development substantially influence the distribution and quality of wetland resources. The alteration of land use in watersheds and development adjacent to wetlands can change the rate, volume, drainage patterns, and composition of runoff. These changes can increase pollutant loads (e.g., nutrients and contaminants) and alter water flow (i.e., surface runoff and groundwater) that enter wetland areas, diminishing ecological function (Wigand et al. 2003). Development also has direct impacts on wetlands. For example, dock and pier development directly impacts marsh habitat and is also related to indirect impacts associated with recreational boating (e.g., increased turbidity, pollutant discharge, and prop scarring) that contribute to the degradation of marsh systems.

Salt marshes are commonly crossed by highways, roads and railroads of various dimensions. These features bisect tidal marshes, fragmenting systems into smaller parts and reducing the natural tidal flushing of the marsh. Culverts are frequently placed under roadways to allow tidal passage, and many of these culverts are not properly sized and create tide restrictions. The influence of tides is the major environmental factor affecting salt marsh ecology, and tidal height variations play an important role in the zonation of marsh plant communities. Tide restrictions do not allow for the normal exchange (inundation and draining) of water, causing degradation of the landward (restricted) salt marsh.

Agencies, like the Massachusetts Office of CZM's Wetland Restoration Program, are working with local partners and the private sector to identify and restore marshes degraded by tide restrictions (e.g., Costa et al. 2002). There are also pilot efforts to quantify the relationship between watershed development and salt marsh condition (e.g., Carlisle et al. 2003).

## STATUS OF ESTUARINE AND MARINE WETLAND HABITAT

The greatest loss of wetlands occurred between the 1950s and 1970s in the United States. Following World War II, the United States was characterized by rapid urbanization and coastal development, resulting in half of the coastal wetlands being destroyed in the lower 48 states (Tiner 1984). Wetlands were drained, filled and converted to other terrestrial lands (Dahl 1990). Estuarine wetlands are still areas of concentrated development, especially for developers of residential and resort housing and marinas.

Urbanization – residential and commercial development – was attributed to over 90% of the loss to coastal wetlands. Urbanization also accelerated pollution to coastal wetlands, diminishing wetland quality and function. Rising coastal population and economic growth created a high demand and market, which continues today, for coastal real estate; therefore, wetlands near urban centers traditionally concentrated development and remain under constant development pressures and pollutant insults.

Since the 1970s, the rate of wetland loss has substantially decreased due to strict regulations and increased awareness of wetland values. The USFWS studied the national status and trends of wetlands from 1986 to 1997 (Dahl 2000). The study estimated that 5.3 million acres of estuarine and marine wetlands existed in 1997, representing a 10,400-acre loss from 1986. The primary cause of wetland loss between 1986 and 1997 was development and open water intrusion (conversion of vegetated wetland to open water). These national trends serve as a proxy for the status of marine and estuarine wetlands in Massachusetts.

State-Wide

Massachusetts contains more salt marsh than any state in New England, and is second to Maine in tidal habitat area. As compared to Massachusetts, Maine has more tidal flat habitat due to its large tidal range and longer coastline.

Salt marsh and tidal flat habitat maps, available through MassGIS (2003), were created by interpreting aerial photography (1:5,000 and 1:12,000 scale) from the 1990s and field verifying aerial signatures (MassGIS 2003). The salt marsh and tidal flat habitat is stored as geographic information system (GIS) data. The wetland habitat maps and GIS data are for planning purposes only, but provide the best available statewide coverage of wetland resources.

The GIS data show that Massachusetts contains at least 45,435 acres of salt marsh (this is an underestimate, due to the "clipping" of the data to align with the state GIS indexing scheme (see MassGIS 2003 for details; Carlisle personal communication)). Tidal flat habitat in Massachusetts was calculated from an analysis of pre-1990 data and covers 469,600 acres (Field 1991). The same study identified 47,200 acres of salt marsh coverage (Field 1991). The current maps do not indicate the historic distribution and abundance of salt marsh and tidal flat habitat or the current or historic quality of salt marsh and tidal flat habitat.

There is no thorough assessment of changes in wetland resources through time for Massachusetts, though several studies demonstrate marsh-specific changes for specific time periods. The lack of a comprehensive database limits the analyses of trends in wetland distribution and quality. National trends are useful to evaluate changes, but specific details of Massachusetts wetlands would be extremely helpful to document and understand changes in wetland habitats and quality.

Regional Assessment

Discrete areas of coastal wetlands are relatively small in Massachusetts, compared to extensive marshes in the mid-Atlantic and southeast United States. Marshes have suffered from considerable filling, such as the historic marshes of Boston that were filled to create the city (e.g., Back Bay and Logan Airport were originally salt marshes). The variation in geology and tidal regime influences the distribution and abundance of wetland habitat in Massachusetts. Coastal areas of Massachusetts Bay generally support relatively small marshes; although, the largest marsh complex of New England is found northwest of Cape Ann from western Gloucester to the New Hampshire border. Many areas of Cape Cod (Cape Cod Bay, outer Cape, and southern Cape), Nantucket, Martha's Vineyard, and the Buzzards Bay coastline are lined with salt marsh habitat. Examples of salt marsh habitat that represent large and relatively undisturbed salt marsh systems are the Great Marsh complex (Salisbury, Newbury, Rowley, Ipswich, Essex and Gloucester), Nauset Marsh (Eastham and Orleans), and Sandy Neck (Barnstable). Tidal flat habitat is found throughout Massachusetts, with extensive tidal flats found in estuarine systems and along eastern Cape Cod Bay (Wellfleet to Yarmouth).

The following selections summarize regional trends based on existing studies that documented temporal changes in particular marshes. From 1977 to 1985/86, the area from Plum Island to Scituate lost 17.80 acres of estuarine wetlands to commercial business development, highway construction, ditching, and residential housing development (Foulis and Tiner 1994). The Neponset watershed contained 311.64 acres of estuarine wetlands and exhibited no change between 1977 and 1991 (Tiner et al. 1998). A gross spatial analysis, based on Costa (1988) and MassGIS (2003), demonstrated no appreciable loss of salt marsh coverage in Buzzards Bay from the 1980s to 1990s. The limited studies that are available for Massachusetts show little loss of salt marsh habitat in the past several decades.

Trends in tidal flat habitat are largely unknown, and no studies were found that describe changes in Massachusetts. The distribution of tidal flat habitat mapped by DEP provides fundamental data on current tidal flat distribution, but examination of historic losses of tidal flat habitat would be useful to understand changes in the extent and quality of this valuable nearshore habitat.

CZM and USFWS are currently examining long-term changes (early 1900s to late 1990s) in salt marsh habitat to provide a thorough assessment of status and trends in salt marsh distribution on Cape Cod, Nantucket, Martha's Vineyard and greater Boston Harbor (Carlisle personal communication). The CZM-USFWS project will provide fundamental information on changes in salt marsh habitat.

## SUMMARY

Estuarine and marine wetlands are highly productive areas found between terrestrial and ocean environments and provide a diversity of ecological and economic values. The distribution and quality of wetlands have not been well documented through time. The information that is available, such as national and watershed-specific studies, shows a tremendous decline in marsh distribution during the 1950s and 1970s. Rates of wetland loss decreased because of new regulations in the 1960s and 1970s. Watershed and coastal development continue to adversely influence wetland integrity and function.

Estuarine and marine wetlands are critical resources to the environmental integrity and economic sustainability of Massachusetts and require thorough monitoring to inform management decisions to protect and restore wetland habitats. A comprehensive monitoring approach would improve the understanding of anthropogenic and natural effects to wetlands and management of these important coastal habitats.

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## 2. SEAGRASS HABITAT

Seagrass, also referred to as submerged aquatic vegetation, are rooted, flowering plants that inhabit nearshore marine and estuarine systems throughout Massachusetts. Widgeon grass (*Ruppia maritima*) and eelgrass (*Zostera marina*) are seagrass species that inhabit Massachusetts coastal waters. Since eelgrass is more abundant and widespread than widgeon grass in Massachusetts coastal waters, the focus of this report is eelgrass.

All life cycles of eelgrass occur underwater (flowering, pollination and seed germination) and are common to coastal, temperate waters in the northern hemisphere (Pacific and Atlantic Oceans). Eelgrass grows in brackish to marine waters, tolerates a wide range of temperatures and is found from the intertidal zone to approximately 10 m below mean low water (eelgrass was found deeper than 40 feet in Cape Cod Bay and Salem Sound). The depth of eelgrass growth is primarily mediated by the water column light environment (i.e., clearer water supports deeper growth). A range of sediment types, current and tidal regimes and shorelines support eelgrass growth, but eelgrass is predominantly found in calm, nearshore waters with soft sediments (e.g., mud and sand).

The cover of eelgrass on the seafloor is variable, ranging from extensive meadows to patchy submerged clusters and thin, low-density beds. Regardless of eelgrass density, eelgrass is a prolific primary producer, supports diverse animal communities, stabilizes sediments, and filters the water column. Eelgrass produces substantial volumes of organic matter that is fundamental to detritus-based food webs, and marine species (e.g., water fowl, crabs and fishes) directly feed on eelgrass. Eelgrass provides critical habitat for fishes, crabs, clams, and other invertebrates. Bay scallops and American lobster, for example, are two economically important species that inhabit eelgrass habitat. Species less known, such as pipefish, sea horses, and gobies (fish species), sea worms, snails, crabs, and algaes, require eelgrass for survivorship and growth. In addition to its value as food and habitat, eelgrass stabilizes seafloor sediments. The physical characteristics of beaches adjacent to eelgrass bed can substantially change, and shorelines erode when eelgrass beds reduce in size and cover or disappear.

The Massachusetts Department of Environmental Protection (DEP) mapped the distribution of seagrass from 1993 to 1996 (MassGIS 2003). The primary objective of the mapping project was to identify the distribution of eelgrass. Widgeon grass was also found in the study area, but the coverage of the mapping project did not include all potential widgeon grass habitat. The DEP project provided the first statewide assessment of eelgrass abundance. Prior to the statewide mapping, there was little rigorous documentation of the extent and quality of seagrass habitat; therefore, quantitative documentation of trends in seagrass abundance is limited. Mapping by DEP continues on a three to five year cycle, and an updated map will be completed to assess the distribution of eelgrass and evaluate changes in distribution from the first map (updated map is scheduled for completion in spring 2004; C. Costello personal communication). The mapping project is providing the foundation for future analyses of spatial and temporal trends. This section summarizes human and natural influences to seagrass habitat, describes the status of eelgrass habitat, and qualitatively assesses temporal changes in eelgrass distribution.

## ANTHROPOGENIC AND NATURAL INFLUENCES OF EELGRASS HABITAT

Eelgrass abundance and distribution fluctuates through time and space due to natural variability. Disease, storms and ice scour, natural sedimentation, and bioturbation influence the quality and extent of eelgrass populations. Wasting disease (caused by slime mold, *Labyrinthula*) is naturally occurring and has had large-scale effects on eelgrass populations. Climate change and sea level rise could also have substantial effects on eelgrass habitat by changing salinity, temperature and tidal regimes and inundating existing suitable habitat. In most cases, eelgrass beds recover from natural events (Costa 1988).

Human-induced impacts to eelgrass populations are evident throughout the state. Physical and chemical insults degrade, reduce and remove eelgrass habitat. Physical impacts, such as scarring from boat propellers, anchors and mooring chains, dredging, and destructive fishing, degrade eelgrass populations. Mooring fields, navigation channels, and aquaculture (e.g., shellfish seeding) are found in areas of historic and existing eelgrass habitat (i.e., shallow waters). The presence of these disturbances in protected bays effectively eliminates eelgrass habitat. Coastal structures (e.g., dock and piers and armored shorelines) reduce available habitat and frequently change natural conditions (e.g., current and sedimentation patterns), leading to loss of eelgrass habitat. In addition to the physical impacts and habitat alterations identified, human activities are often associated with increased turbidity that decreases the light available to eelgrass. Minor changes in light availability can substantially influence eelgrass quality.

Poor water quality and decreased clarity result in the largest scale loss of eelgrass habitat. Water clarity is synonymous with light availability, and light available to eelgrass is dictated by phytoplankton abundance, algae abundance and cover, and sediment suspension (turbidity). Eutrophication (i.e., nutrient over enrichment) increases growth of algal epiphytes (algae species that grow on eelgrass) and phytoplankton that absorb light in water column and prohibit light from reaching eelgrass. Eutrophication decreases water clarity and degrades eelgrass habitat. Low water clarity and high nutrient levels promote the proliferation of benthic and drift algae because these types of algae often have lower light requirements than eelgrass, smothering eelgrass and out-competing eelgrass for space. Other pollutants that influence eelgrass habitat enter coastal waters and degrade and kill eelgrass, such as herbicides used for lawn care by homeowners and larger landscapes (e.g., golf courses).

## STATUS OF EELGRASS HABITAT

Few studies systematically document temporal changes in eelgrass habitat. And – documentation that does exist is often qualitative, hindering the understanding of natural fluctuation and human impacts on eelgrass. Studies that demonstrate change in eelgrass abundance and document causes for changes in eelgrass habitat are plentiful outside of

Massachusetts (see Fonseca et al. 1998), and these studies can serve as a useful guide to understand natural and human-induced impacts to seagrass and long-term trends in eelgrass abundance. In Massachusetts, Colarusso (personal communication) and Costa (1988) provide the most thorough assessment of historical changes in eelgrass abundance.

Colarusso (personal communication) summarizes gross statewide trends of eelgrass populations, excluding Buzzards Bay. Historic trends in eelgrass abundance of Buzzards Bay were studied by Costa (1988). Comprehensive information on eelgrass quality, such as shoot density, coverage, and growth, are scarce, but there are studies (e.g., Dexter 1985; Short and Burdick 1996) that provide detailed examination of particular harbors that can be viewed as a proxy for regional trends (see cited references and suggested readings for more detail).

State-Wide

Massachusetts DEP mapped the statewide coverage of seagrass to provide a conservative estimate of eelgrass distribution. The maps were created by interpreting aerial photography (collected 1993-1996) and field verifying seagrass photographic signatures (MassGIS 2003). Approximately 39,200 acres of eelgrass and 4.5 acres of widgeon grass were mapped in Massachusetts (MassGIS 2003; Colarusso personal communication). These maps are frequently used as a baseline, but the current maps do not incorporate recent changes in eelgrass or indicate the historic extent or quality of eelgrass habitat.

The capability of mapping large areas of eelgrass is a relatively new development; therefore, quantitative change analyses are only available for the recent past and future. Temporal changes in eelgrass abundance were, however, observed on regional and local scales. These changes were documented in directed studies or have been noted by anecdotal information and personal observations.

Wasting disease decimated eelgrass populations throughout the state, along with the entire North Atlantic Ocean, from 1930 to 1933. Site-specific information on the recovery of eelgrass from the 1930s is rare, but eelgrass abundance generally recovered in 30 years for most areas. However, there is evidence that eelgrass populations in certain areas never recovered from the wasting disease (summarized by Costa 1988). The greatest recovery from wasting disease occurred in the 1950s-1960s. Eelgrass abundance fluctuated prior to the 1930s, but because assessments before 1930 are rare it is difficult to assess changes before this time. The outbreak raised awareness of eelgrass value to coastal environments.

Massachusetts Bays

The Merrimac River, Plum Island Sound, Ipswich, Essex Bay and Newburyport Harbor were devoid of eelgrass in 1995 (MassGIS 2003). This lack of eelgrass indicates a substantial loss since the 1940s. Dexter (1985) documented fluctuation in eelgrass abundance and distribution of Cape Ann from 1933 to 1984. The Cape Ann study, supplemented by recent observations, demonstrated that eelgrass generally recovered from the wasting disease outbreak but disappeared in the Annisquam River by the mid-1980s and early 1990s. Eelgrass persists on the northwest shore of Cape Ann, which is well flushed, compared to the estuarine waters of Annisquam River. The Cape Ann study may serve as a proxy of trends in eelgrass abundance of northern Massachusetts Bay.

Salem Sound supports a consistent and relatively continuous eelgrass meadow from the mouth of the Danvers River in Beverly to Manchester Harbor. These meadows persisted through periods of depressed water quality and currently grow in the deepest water of the state, an indication of good water quality (Colarusso personal communication). Eelgrass was recorded in Salem and Marblehead Harbor (MassGIS 2003), but recent observations (2002-2003) show eelgrass at diminished levels or absent (personal observation). The construction of an underwater gas pipeline (i.e., Hubline) also removed areas of eelgrass and affected eelgrass habitat by increasing turbidity during construction.

Eelgrass mapped in the Swampscott, Nahant and Lynn Harbor is relatively stable; although, a dredging project in Swampscott during the 1990s removed a substantial area of eelgrass. The disturbed eelgrass appeared to recover by 2003 (Colarusso personal communication), probably because Swampscott has well-flushed waters that provide a suitable water column light environment for recovery.

Boston Harbor historically supported large areas of eelgrass, but eelgrass habitat has greatly diminished since the 1800s and early 1900s. Eelgrass was noted as abundant in 1909, sparse in the 1940s, and currently (based on 1995 map) exists in only a few locations (i.e., near Logan International Airport, Bumpkin Island and World's End (Hingham) and Allerton Harbor (Hull); MassGIS 2003).

Several protected areas contain eelgrass in southern Massachusetts Bay. The eelgrass population is relatively consistent in Scituate Harbor, although a recent dredging project removed eelgrass habitat. Cohasset Harbor supported eelgrass in the inner and outer portions of the embayment in the early 1990s, but recent observations (2003) noted the loss of eelgrass in the inner harbor. A large, continuous bed exists in Duxbury and Plymouth and has been persistent for many years.

<u>Cape Cod Bay and Outer Cape Cod</u>

Cape Cod Bay supports a number of small and large expanses of eelgrass habitat. Eelgrass beds are found along the Cape Cod Canal and coastal waters of Sandwich, Yarmouth and Dennis. Eelgrass was documented along Sandwich in 2003. The 1995 map does not show eelgrass in Sandwich waters, indicating a possible expansion of eelgrass distribution. Eastern Cape Cod Bay has the largest contiguous meadow in the state, with extensive coverage of eelgrass found from Provincetown Harbor to Brewster, including a large area of eelgrass habitat on Billingsgate Shoal (Wellfleet). The abundant eelgrass in eastern Cape Cod Bay was not noted in a 1940s study, so the current distribution may demonstrate an increase in abundance. However, eelgrass was noted for Hatches Harbor (Provincetown) but was not mapped in 1995 (MassGIS 2003), representing a possible loss of eelgrass habitat. Historic and contemporary presence of eelgrass shown on maps for Cape Cod may be a factor of sampling methodology and description of eelgrass habitat, with particular techniques more or less efficient at identifying eelgrass.

Nauset marsh (Eastham and Orleans) contained eelgrass habitat mixed with red and green algae in 1985-1986, during a study of fish and invertebrate assemblages (Heck et al. 1989; Heck et al. 1995). Eelgrass was not found in Nauset Marsh in 1995 (MassGIS 2003). The mix of algae within the eelgrass habitat in 1985-1986 may have been a natural occurrence or a sign of excess nutrients. Regardless of the cause of loss, the fact that eelgrass was not mapped in 1995 indicates a loss of habitat. Pleasant Bay and the Monomoy Islands support stable eelgrass meadows, as documented by studies in 1900s, 1940s, 1980s, and recent mapping (1995).

Southern Cape Cod and the Islands

Eelgrass is widely distributed along the southern Cape Cod shoreline. Eelgrass abundance was greater prior to the wasting disease outbreak in the1930s, but recovered and seems relatively stable in well-flushed waters (e.g., open coast). Substantial coverage and volume of macroalgae, such as *Codium fragile* and *Ulva* spp., mix with eelgrass habitat in southern Cape waters. The proliferation of algae species is a relatively recent phenomena. Eelgrass habitat has fared quite differently in the enclosed embayments of southern Cape Cod, with dramatic losses noted in several shallow inlets and embayments.

The loss of eelgrass habitat and cause of eelgrass habitat degradation is thoroughly documented in Waquoit Bay (summarized from Costa 1988; Short and Burdick 1996). Eelgrass recolonized Waquoit Bay after the 1930s. Eelgrass grew abundantly nearshore (especially along the eastern shoreline) and was found in the deepest parts of the bay in the 1950s and 1960s. After 1965, eelgrass began to disappear in deeper portions of the bay. By the mid-1970s, the bay shoreline did not support eelgrass. The loss of eelgrass was attributed to decreased light availability because of increased epiphyte (plant growth on the eelgrass blades) and phytoplankton growth and proliferation of dense drift algae (Costa 1988). Short and Burdick (1996) further studied changes in eelgrass habitat and documented similar trends of diminished distribution and documented dramatic declines in eelgrass abundance. The loss of eelgrass was attributed to increased nitrogen loading associated with increased watershed development in the Waquoit Bay systems. No eelgrass is currently found in the central basin of Waquoit Bay (MassGIS 2003). The studies of Waquoit Bay describe the effects of watershed development, nutrient enrichment and algae proliferation on eelgrass habitat. These studies provide a reasonable record of other losses of eelgrass in shallow water embayments of southern Cape Cod, the islands and Buzzards Bay.

Martha’s Vineyard and Nantucket contain extensive eelgrass meadows. The enclosed embayments and northern shorelines are lined with eelgrass. Enclosed waters show signs of degradation, such as high epiphytic loads and macroalgae, that diminish eelgrass habitat quality. Cape Pogue was studied in 2002, and notable volumes of macroalgae, particularly *Codium fragile*, was observed mixed with eelgrass (personal observation). The 1994 eelgrass map did not note macroalgae occurrence in Cape Pogue (MassGIS 2003).

Buzzards Bay

The most detailed assessment of changes in eelgrass abundance for Massachusetts is a study from Costa (1988) of Buzzards Bay, but this study is dated and does not document current changes in eelgrass habitat. For the purposes of this report, the study of Buzzards Bay (Costa 1988) is summarized and important details are noted. Eelgrass was widespread in Buzzards Bay prior to 1930. Bay-wide eelgrass populations were devastated in 1930-1933 by the outbreak of wasting disease. Eelgrass slowly recovered from the late 1930s, and greatest increases in abundance occurred in the 1960s and 1970s. All areas, however, did not recover from the wasting disease episode.

Eelgrass covered 11,120 acres in 1988 (Costa 1988). Evidence documenting change of eelgrass through time is not complete, but data available suggests eelgrass abundance prior to the disease outbreak (in 1930s) was greater than the 1988 abundance. The 1994 map (MassGIS 2003) showed further loss of eelgrass coverage, with eelgrass covering 6,721 acres.

The cause of diminished eelgrass populations can be site-specific, but severe climatic events (e.g., icing and ice scour) and declining water quality are the biggest factors effecting eelgrass habitat in southeastern Massachusetts (Costa 1988). Particular embayments, however, have seen modest increases in eelgrass distribution in recent years. Costa (1988) studied 12 embayments to investigate temporal changes in eelgrass distribution, and MassGIS (2003) shows the 1994 distribution of eelgrass. The two data sources are summarized to provide additional detail on the changes in distribution and potential causes of changes (please see Costa 1988 and MassGIS 2003 for more detail).

Eelgrass disappeared from protected waters of upper estuaries in the Westport Rivers, Apponagansett Bay, Little Bay, Great Neck, Wareham Rivers, Sippican Harbor, Clarks Cove, Buttermilk Bay, Megansett and West Falmouth Harbor (Costa 1988; Hughes et al. 2002; MassGIS 2003). The loss in the upper estuaries are due to decreased water clarity from nutrient loading and increased epiphyte and algal cover. Increased recreational boat traffic may also contribute to decreased water clarity due to resuspension of sediments by propeller wash and shoreline erosion from wakes. Drift algae, frequently associated with nutrient loading, proliferated in the past couple of decades throughout Buzzards Bay. These algae species smother eelgrass seedlings, adult shoots, and available eelgrass habitat.

New Bedford Harbor, including Acushnet River and outer harbor waters, endured major physical changes (e.g., development of the port and construction of the hurricane barrier) and substantial chemical insults (e.g., PCBs, heavy metals, and sewage). These insults substantially reduced eelgrass populations and available eelgrass habitat, but recent eelgrass distribution has expanded in the outer harbor. Sewage treatment and combined sewer overflow control upgrades improved water quality in the harbor.

Outer estuarine waters and enclosed waters surrounded by limited watershed development tend to have relatively stable eelgrass beds. Substantial areas of the open Buzzards Bay coast are lined with eelgrass (MassGIS 2003). Nasketucket Bay, East Bay and West Island (Fairhaven), for example, are relatively undeveloped coastlines and contain consistent eelgrass beds. Lower portions of estuaries, such as Westport Rivers, Apponagansett Bay, Sippican Harbor, southern portion of the Cape Cod Canal, and West Falmouth Harbor, demonstrate relatively persistent eelgrass beds. Outer estuaries, however, that are adjacent to upper estuarine waters that show signs of eutrophication are vulnerable to further loss of eelgrass habitat.

## SUMMARY

Eelgrass habitat is a critically important resource in Massachusetts waters. There are no long-term records that document the change in eelgrass abundance or quality. The recent DEP mapping project provided the first statewide coverage of eelgrass. The patchwork of historic information, targeted studies, and recent observations allows an evaluation of changes in eelgrass distribution. This evaluation, however, does not indicate changes in habitat quality. Historically there were substantial losses of eelgrass habitat in Massachusetts Bay and, more recently, large-scale losses were noted in Buzzards Bay and Cape Cod.

Embayments in Massachusetts Bay, including waters north and south of Boston, and western Cape Cod Bay tend to be well-flushed, cool and low in nitrogen. These systems generally provide suitable environmental conditions for stable eelgrass populations, and recent surveys document minor changes to eelgrass habitat. There are exceptions however, because impacts associated with physical disturbance, coastal development, and disease have diminished eelgrass abundance in areas of northern Massachusetts Bay.

Historic abundance of eelgrass was substantially diminished in enclosed waters of southern Cape Cod and Buzzards Bay. These estuaries tend to be shallow, semi-enclosed systems, with relatively warmer water temperature. Cape Cod and Buzzards Bay experienced substantial coastal and watershed development in the past several decades and septic systems are more widely used in this region, resulting in greater delivery of nitrogen to coastal waters. The shoreline of Buzzards Bay, southern Cape Cod, and the Islands supports extensive eelgrass abundance, but expanding watershed development, increasing nutrient loading and the widespread occurrence of algae (drift, attached and encrusting) raises concern of further degradation of eelgrass habitat.

Massachusetts has the greatest quantity of eelgrass of any New England state. Current statewide monitoring includes mapping eelgrass distribution at a three to five year cycle. Eelgrass mapping provides fundamental information on eelgrass presence, but eelgrass habitat is variable and the location of eelgrass changes through space and time. Environmental requirements of eelgrass and human-induced threats to eelgrass are well described. Water quality and direct disturbance to eelgrass beds are particularly important to eelgrass growth and survivorship, but current management approaches (e.g., state water quality standards and mooring field development) do not ensure the protection of eelgrass. The Massachusetts Estuaries Program, administered by Massachusetts DEP, is researching and developing site-specific data to manage nutrient loading to nearshore waters. This program can provide the basis for identifying water quality standards that will protect eelgrass habitat. The long-term sustainability of eelgrass habitat requires proactive conservation measures, including nutrient loading management and habitat protection.

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## 3. SEAFLOOR HABITAT AND MAPPING

A variety of physical, chemical and biological factors contribute to seafloor habitat type and quality. Substrate type, salinity, temperature, dissolved oxygen and water depth are important physical and chemical factors that affect habitat type, while biological factors such as the presence of particular animal and vegetation communities also contribute to the habitat type and quality. This section describes the types of subtidal (below mean low water) seafloor habitats, primarily defined by the predominant substrate type, but does not review all habitat types or species associations.

The description of seafloor habitat often relies on the assessment of surficial seafloor sediments. The geological composition of the ocean floor is highly variable throughout Massachusetts waters, with the most notable difference occurring north and south of Cape Cod. Glacial scour removed soft sediments from large regions north of Cape Cod leaving the Gulf of Maine with a highly heterogeneous seafloor composed of both soft and hard substrates. In southern Massachusetts, which is part of the middle Atlantic Bight, there is a similar range of substrate types but a higher proportion of sand environments. A large volume of research demonstrates that animal and plant distributions are often closely associated with substrate types; therefore different communities of organisms are generally associated with different substrate types. Table 1 lists major types of seafloor habitats in Massachusetts and some of their notable ecological functions.

Table 1: Seafloor habitat features in Massachusetts (adapted from Auster and Langton 1999).

| SEAFLOOR HABITAT TYPES | ENVIRONMENTAL CHARACTERISTICS AND NOTABLE SPECIES ASSOCIATIONS* |
|---|---|
| Rock Ledge and Piled Boulders | - Deep interstitial spaces of variable sizes<br>- Hard substrate provides attachment for a variety of vegetation and unique invertebrate assemblages (kelp, soft corals, anemone)<br>- Fish, such as redfish, frequently congregate |
| Partially Buried Boulders | - Exhibit high surficial relief with little interstitial space<br>- Valuable shelter for mobile species, such as redfish and tautog, and attachment surface for invertebrates |
| Cobble and Gravel with Epibiota<br><br>Epibiota are creatures and plants living on seafloor surface. | - Attached fauna and flora, such as sponges and macroalgae, add spatial complexity to cobble substrate<br>- Sediments and attached creatures provide microhabitats for diversity of creatures<br>- Important nursery and fishery habitat for diversity of species (e.g., sea scallops, American lobster, Atlantic cod) |
| Cobble and Gravel | - Provide small interstitial spaces<br>- Important settlement nursery habitat for variety of fishes and crabs (e.g., cod and lobster)<br>- Important attachment habitat for invertebrates and fishery habitat |
| Shell Aggregates | - Complex interstitial spaces used for shelter<br>- Invertebrates attach to shells |
| Biogenic Structure (on relatively smooth bottom) | - Biological growth – epifauna and algae – provide shelter and structure to mobile creatures on the seafloor<br>- Burrows and depressions formed by mobile creatures are inhabited by many organisms |
| Sand | - Sand waves often form troughs and peaks, providing limited surficial relief<br>- Organisms find shelter from currents and predation in troughs<br>- Flounder species, surf clams and quahogs frequently associated |
| Smooth Sand or Mud | - Areas with little to no vertical structure – flat benthos<br>- Support number of invertebrates, including unique species assemblages (cerianthid anemones, tube-dwelling amphipods, sea pens) and fishes (especially flatfish)<br>- Important shellfish (e.g., soft-shell clam, razor clam) habitat |

* Species noted are meant only as examples. Thorough studies on species associations are available, but this section is not a comprehensive summary of the ecological function of each seafloor habitat type. Seafloor habitats do not typically function independently; that is – many marine organisms require a range of habitat types throughout their life cycle. This list presents the habitat types by predominant substrate in isolation, but these substrate types frequently occur in combination, which imparts different ecological functions.

## HUMAN-INDUCED IMPACTS TO SEAFLOOR HABITAT

There are many direct and indirect impacts to seafloor habitat associated with human activities. Watershed development contributes a variety of pollutants to coastal waters that influence the quality and function of a variety of seafloor habitats. Non-point and point sources of pollution have large scale impacts to seafloor habitats, especially in nearshore waters close to sources. Direct disturbance from construction in ocean waters, such as pipeline installation, have localized impacts to seafloor habitats. The effects of fishing, including bottom-tending gear, has wide-ranging impacts (spatial and temporal) to seafloor habitats and the composition of fauna associated with habitats (Auster and Langton 1999). These and other anthropogenic impacts combine to degrade seafloor habitats and change the quality and function of the diversity of seafloor habitats in Massachusetts waters.

## MAPPING AND MANAGING SEAFLOOR HABITAT

Coastal and fishery resource managers are frequently tasked with evaluating the impact of development projects or uses in the coastal zone without sufficient knowledge of the seafloor habitat types that may be impacted by proposed projects. Aside from the eelgrass mapping, the distribution, types and quality of subtidal seafloor habitats are largely unknown for Massachusetts. This lack of information hinders the management of marine ecosystems. An essential component of effective management is knowing the distribution of seafloor habitats, so that exemplary, unique, and sensitive habitat types can receive a higher level of resource assessment for permit review or even be subject to proactive protection measures.

In contrast with marine resource managers, terrestrial and freshwater managers have many types of maps that depict information vital to management decisions. For example, the United States Geological Survey (USGS) created topographic maps (scale=1:25,000) of the terrestrial portion of the United States. These maps depict elevation contours, infrastructure, hydrological features and forested areas. Marine resource managers lack this type of information, unless the site was previously examined for a proposed project. Currently, marine resource managers in Massachusetts only have a very coarse scale map (1:1,000,000) of sediment distribution (Poppe et al. 1989), higher resolution for small areas (e.g., one harbor) or completely lack any information on subtidal resources from which to infer the distribution and/or condition of seafloor habitats.

In the absence of spatially explicit information regarding the distribution and condition of seafloor habitat, marine resource managers are forced to rely on project specific resource characterizations to make management decisions. This leads to an uncoordinated, piecemeal assessment of the condition of the seafloor and its associated species.

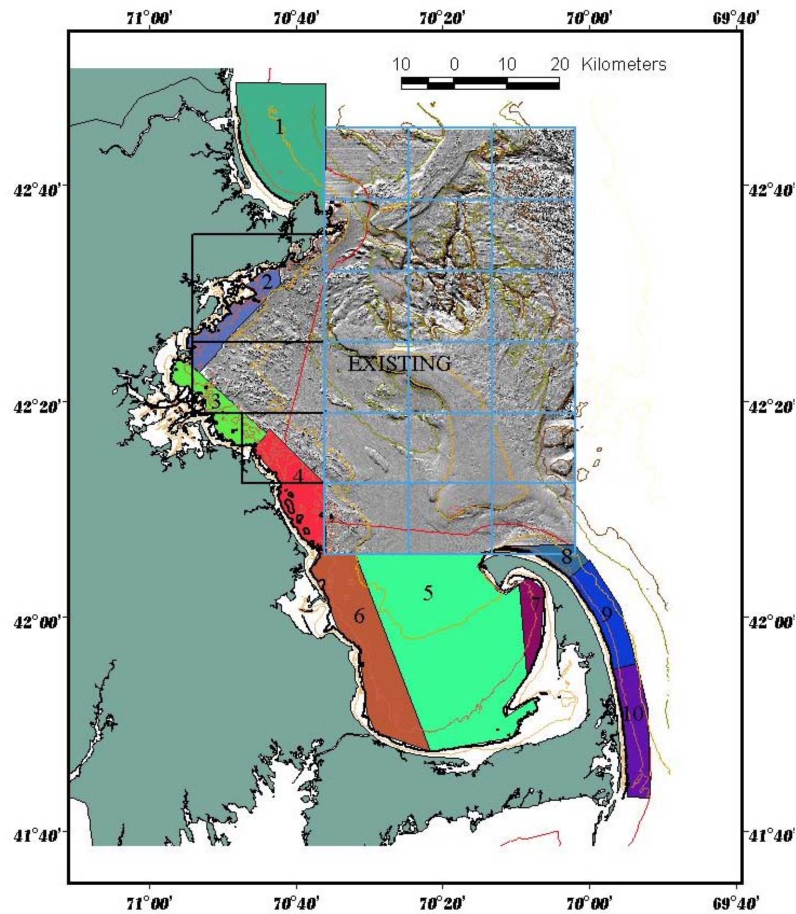


Figure 1: Map showing extent of current and proposed mapping for waters greater than 10 m depth in Massachusetts' Acadian province. Figure courtesy of Brad Butman, USGS.

Recent technological advances in the use of acoustics to derive information about the seafloor geology has made seafloor habitat mapping feasible for large areas. Seafloor geology and bathymetry were collected over large areas within and adjacent to state waters (Figure 1, Stellwagen Bank National Marine Sanctuary mapping; USGS 2003).

The type or quality of seafloor habitat encompasses more than geology and bathymetry. However, these physical data types are efficiently collected at large geographic scales and are fundamental data for subsequent assessment of animal and plant communities. Biological data is essential for the description of seafloor habitat. Seafloor habitat maps, showing seafloor substrate type, topography and species associations are a valuable planning tool to insure future protection efforts are habitat based and include representatives of all habitat types in a region.

STATUS OF ACOUSTIC MAPPING OF THE SEAFLOOR

The recent development and application of acoustic mapping systems, such as multibeam and side scan sonar, to map the distribution of seafloor substrates and bathymetry provides highly detailed images of the seafloor. These detailed maps are useful in determining the type and extent of seafloor habitats. Several large-scale mapping projects in Massachusetts are planned or underway.

The Massachusetts Office of Coastal Zone Management (CZM) is partnering with the US Geological Survey (USGS) to conduct seafloor mapping in selected areas of

Massachusetts (using mitigation funds from a natural gas pipeline installation in Massachusetts Bay). Various types of acoustic instruments are used to measure seafloor topography, surficial geology (sediment distribution and bedforms) and the subbottom profile of various sediment layers. Two major sections of Massachusetts Bay were recently surveyed using acoustic instruments (Figure 1). Section 1 extends from Cape Ann to the New Hampshire border and was surveyed, using multibeam sonar, by Science Applications International Corporation (SAIC, Newport, RI). The survey boundary ends near the western edge of the University of New Hampshire's mapping of Jeffrey's Ledge (not shown). The comparatively shallower South Essex Ocean Sanctuary (which extends from Cape Ann to Boston Harbor; section 2) was surveyed using sidescan sonar and high-resolution seismic profiling by USGS in fall 2003. The mapping in the South Essex Ocean Sanctuary adjoined the northeast border of existing USGS mapping of Stellwagen Bank and western Massachusetts Bay (Figure 1). Sections 3 to 10 were delineated based on water depth and will be mapped as funds become available. The outcome of the ongoing and planned mapping is a comprehensive, seamless map of seafloor geology and bathymetry for Massachusetts Bay, Cape Cod Bay and outer Cape Cod. Plans are also developing for similar surveys of southeastern Massachusetts. The final map will not include shallow waters (i.e., <10m).

The US National Ocean Survey's Office of the Coast Survey (OCS) is responsible for maintaining and updating navigation charts, and they periodically survey major ports to obtain high-resolution water depth (bathymetry) and seafloor topography data. In a 2001 survey of Boston Harbor and approaches, the OCS obtained multibeam and sidescan sonar coverage of the seafloor. Sidescan sonar data from Boston Harbor will be processed into a map of surficial sediment distribution and bathymetry. The eastern edge of the Boston Harbor sidescan survey adjoins the western edge of Stellwagen Bank and western Massachusetts Bay mapping (Figure 1).

In addition to the Boston Harbor and approaches survey, OCS recently completed acoustic surveys of Gloucester Harbor, Woods Hole Harbor and a small section of the seafloor off the southeastern point of Monomoy Island. CZM and OCS are determining the possibility of analyzing the existing and future survey data to create seafloor habitat maps.

After an acoustic survey, biological and geological sampling of the seafloor is critically important to groundtruth or verify the interpretation of the acoustic data. Groundtruth sampling involves acquisition of a sediment core for sediment grain size analysis and a range of techniques (e.g., bottom photographs and/or grab samples) to obtain biological data. Processing biological and geological samples is time consuming and therefore, the production of a seafloor habitat map lags substantially behind the completion of the acoustic survey. Seafloor habitat maps of the recent acoustic surveys in Massachusetts Bay and Boston Harbor are planned to be completed in winter 2004.

## SUMMARY

Seafloor habitats are a valuable component of the ocean environment in Massachusetts. The type, distribution and quality of seafloor habitat strongly influence the abundance of non-commercial and fishery species. Additionally, the productivity, biological diversity and functions of nearshore and offshore ecosystems are strongly affected by the quality of seafloor habitats. The ecological function of many seafloor habitats are well described, such as the importance of cobble habitat to American lobster and Atlantic cod and rock ledge to invertebrate communities. However, the relationships between seafloor habitats and biological communities is a field of discovery and research is required to understand the value and function of seafloor habitats and species assemblages. Furthermore, the distribution of these habitats is largely not known. Ocean resources planning is limited due to the lack of seafloor habitat maps. Nearshore-shallow waters and offshore-deep waters contain a variety of habitats and spatial information regarding the distribution and extent of these habitats is needed to improve ocean resources management. Massachusetts is actively pursuing opportunities to obtain seafloor habitat maps, such as the collaborative mapping of nearshore Massachusetts Bay by CZM and USGS, and Massachusetts Division of Marine Fisheries efforts to obtain mapping equipment, and the results of these endeavors will facilitate future monitoring, research, and management of seafloor habitats.

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## 5. SOFT CORALS, KELPS AND WATER COLUMN HABITATS

The following is a brief description of soft coral, kelp bed and water column habitats. This section highlights these habitat types because they support biologically diverse and productive marine communities. Additional habitats and environmental features are also important to sustain the function and values of Massachusetts' ocean resources, but are not described in this section. Overall, many other animal and plant species, distinct physical characteristics and chemical properties contribute to the diversity and productivity of ocean environment of Massachusetts.

### SOFT CORALS

Soft corals are suspension feeding invertebrates; their feathery tentacles capture food particles in the water column. Soft corals are generally long lived, with very slow growth rates. It can take several hundred years to reach a height of several meters (Watling and Auster 2003), but their skeletons create microhabitats for a diverse array of smaller organisms. Soft corals are similar to reef building corals (such as tropical coral reefs), except soft corals have flexible skeletons. Soft corals are typically found in deep water and attached to hard substrates. However, some species were found in the Massachusetts region in water only 13 m deep (Theroux and Wigley 1998). These species may occur in deep waters of the Massachusetts coastal zone, particularly off the southeast coast of Nantucket.

The historical distribution and abundance of soft coral was likely reduced due to fishing gear impacts; soft corals are highly susceptible to disturbance by gear that touches the bottom (Koslow et al. 2001). Their slow growth rates imply that recovery from disturbance can be expected to take a very long time. In addition, because soft corals are sessile (attached to the bottom), larval dispersal is their only means of recolonizing after severe disturbance. One soft coral species, *Alcyonium* sp. in Massachusetts is also threatened by predation by an introduced nudibranch, *Tritonia plebia*.

Little to no data are available on the distribution of soft corals in Massachusetts. Limited MWRA hardbottom monitoring from a 2002 survey identified one species of soft coral, *Gersemia rubriformis,* at 23 m depth. Long-term monitoring of communities on vertical rock ledges in the subtidal zone off the Nahant Marine Lab found soft coral communities (Allmon and Sebens 1988). The fact that these two studies observed soft corals demonstrates that these unique and sensitive species can occur in state waters and merit attention.

### KELP BEDS AND SEAWEEDS

Kelp are brown algae that grow up to several meters in length. The most common species in our region are sugar kelp, *Laminaria saccharina,* oarweed, *L. digitalis* and shotgun kelp, *Agarum clathratum.* Kelp are generally found attached to stable rock substrates in cold waters. The distribution of kelp in Massachusetts is likely limited to subtidal rocky habitats north of Cape Cod. Kelps also attach to human-made structures, such as docks and piers. Unfortunately, the distribution and status of kelp beds are unknown in Massachusetts. Kelp are not part of any monitoring program.

Kelp beds are underwater forests that provide refuge for a diverse array of invertebrates and fish, especially juvenile fish. The holdfasts, or root like structures, provide microhabitats for small invertebrates, such as brittle stars and juvenile mussels. Kelps have one of the highest primary productivity rates in the world. They cycle nutrients and are an important food source for grazing echinoderms, mollusks, and crustaceans. Extensive kelp beds reduce current speeds and buffer upland areas from erosion or storm damage. They also provide shelter from physical stresses such as UV (ultra violet) radiation. In areas of the Gulf of Maine, kelp beds are being replaced by the introduced green algae (*Codium fragile* spp. *tomentosoides*; Harris and Tyrrell 2001).

Additional seaweeds species are found throughout Massachusetts coastal waters. A number of brown algae species, collectively known as rockweed, form a highly structured habitat and provide important ecological functions in nearshore waters. The red algae, Irish moss (*Chondrus crispus)* is also a valuable part of nearshore seaweed communities, and was traditionally harvested along many sections of the coast. For example, the south shore of Massachusetts had substantial populations of Irish moss that sustained a productive industry for years.

There is no data on the distribution of kelp beds or other seaweed-dominated habitats in Massachusetts. This productive nearshore marine habitat has not received adequate attention from monitoring or research programs; therefore, trends in abundance and distribution are not available.

## WATER COLUMN HABITATS

Oceanographic features, such as currents, fronts and eddies, are dynamic, interactive and temporally and spatially variable. Massachusetts has semidiurnal tides, major and minor currents, variable fronts and eddies, and large and small riverine discharge. These features are important to ecosystem structure and function. The tidal flux in Massachusetts provides rapid exchange of nutrients, dissolved organic matter and detrital matter from coastal waters to offshore regions; riverine discharges greatly influence nutrient levels in coastal waters; the tidal range and flux affects oceanographic processes (e.g., currents, fronts, eddies, gyres, and seafloor geology) that are associated with the distribution and abundance of biological communities. Fish spawning and early life history development (eggs and larvae) are frequently associated with water column features, and the productivity and success of reproduction can be largely influenced by oceanographic properties. Water column habitats are poorly understood. To fully understand the function of the estuarine and marine environment in Massachusetts, a thorough understanding of pelagic habitats is needed.

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